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Soil-Topographic Site Index for Engelmann Spruce on Granitic Soils in Northern Colorado and Southern Wyoming[1]

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Site index of Engelmann spruce can be estimated from soil depth to the C horizon and elevation. Predictions should be confined to potential spruce-fir sites on granitic soils in northern Colorado and southern Wyoming.

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Site indexes based on heights and ages of dominant and codominant trees are commonly used to express the productive capacity of forest land. Frequently, however, the conventional height-age relationship cannot be used to estimate site quality because either the area has been deforested by fire or logging, or the trees present are too young or otherwise unsuitable for measurement. In those situations, an alternative method of evaluating site productivity is necessary.

One alternative is to base site classification on environmental factors related to site index (Coile 1938). A productivity rating based on the permanent features of soil and topography can be used on any site, regardless of the presence, absence, or condition of the vegetation.

The objective of this study was to develop a prediction equation based on soil and topographic factors that can be used to estimate the site index of Engelmann spruce (Picea engelmannii Parry) growing on granitic soils in southern Wyoming and northern Colorado. The following factors were selected for investigation: (1) aspect, (2) slope percent, (3) slope position, (4) elevation, (5) soil depth to the C horizon, and (6) texture of the B horizon. These were selected because they were found to be most often correlated with site index in similar studies of other species in the Rocky Mountains (Mogren and Dolph 1972, Myers and Van Deusen 1960).

Methods

During the summer of 1971, 129 1/5-acre plots were established in even-aged, natural stands dominated by Engelmann spruce and subalpine fir (Abies lasiocarpa (Hook.) Nutt.) on National Forest land in northern Colorado and southern Wyoming (fig. 1). Plots were confined to stands that met the following criteria:

1. Even-aged (not more than 25 years' spread in the age of dominant trees).
2. Average age of dominants from 60 to 300 years.
3. Topography and stand conditions uniform on and adjacent to each plot.
4. Soils derived from granitic rock.

[1] *Based on a thesis submitted to the Graduate Faculty of Colorado State University in partial fulfillment for the requirements for the degree of Doctor of Philosophy.*

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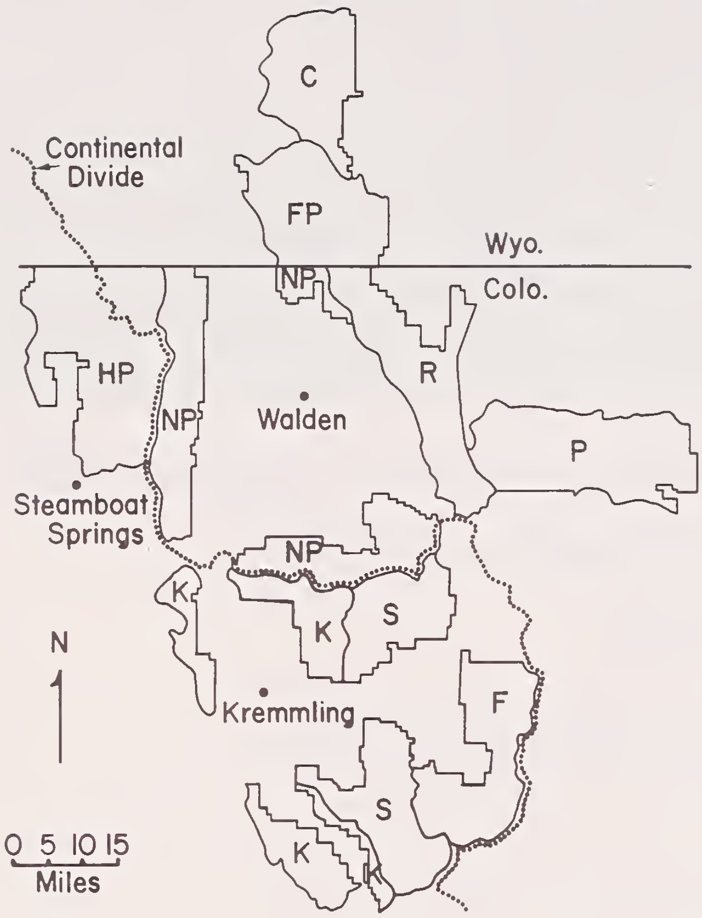

Figure 1.—Study areas were located on nine Ranger Districts of four National Forests in northern Colorado and southern Wyoming, as follows:

Arapaho National Forest, Colorado
F — Fraser District
K — Kremmling District
S — Sulphur District
Roosevelt National Forest, Colorado
P — Poudre District
R — Redfeather District
Routt National Forest, Colorado
HP — Hahns Peak District
NP — North Park District
Medicine Bow National Forest, Wyoming
C — Centennial District
FP — Foxpark District

Plots were not randomly selected, but were chosen so that most or all possible combinations of site index, aspect, slope percent, and elevation were included.

On each plot, six to eight trees were selected for site determination. Only trees that met the following criteria were selected:

1. Dominants or appeared-to-have-been dominants throughout their lives.
2. No evidence of past suppression, or damage from fire, insects, or diseases that may have affected height growth.
3. Sound enough for ring counts.

Heights and ages were measured in the conventional manner. The aspect of each plot was measured with a compass and expressed as the sine of the azimuth clockwise from southeast plus one (Gaiser 1951). Slope percent was measured with an Abney level and expressed as a decimal. Slope position was the paced distance from the bottom of the slope up to the plot center divided by total slope distance, expressed as a decimal. Elevation was measured with an altimeter. A soil pit was dug at the center of each plot and soil depth to the C horizon measured in inches. Soil samples were obtained from the B horizon for textural analysis.

The relationships between site index and the soil and topographic factors were examined in a stepwise multiple regression. Site index at base age 100 years was determined for each plot from height-age curves developed by Alexander (1967). Site index was plotted over each independent variable, and nonlinear relationships were converted to linear form. Independent variables not related to site index were discarded. The remaining variables were tested for significance by analysis of variance.

Results

Two variables can be used to estimate the site index of Engelmann spruce on granitic soils in northern Colorado and southern Wyoming. The equation is:

$$Y = -106.63509 + 62.46021\,(X_1) + 809.39618\,(X_2) \qquad [1]$$

where:
Y = site index in feet;

X_1 = logarithm of soil depth in inches to the top of the C horizon;

X_2 = 1000/elevation in feet.

The multiple correlation coefficient (R) is 0.804, with 65 percent of the variation in site index accounted for. The standard error of estimate at the means of the independent variables is ± 9.00 feet.

Five other independent variables — (1) percent clay in the B horizon, (2) percent sand in the B horizon, (3) sine of the aspect from south-

east plus 1, (4) slope position, and (5) slope percent — were also significant, but made no real contribution to the amount of total variation accounted for (Sprackling 1972).

Figure 2 and table 1 were developed from equation 1 to permit rapid estimates of site index in the field. These data are applicable to spruce-fir sites within the study area where granitic soils vary from 7 to 53 inches to the top of the C horizon and elevations are between 8,600 and 11,200 feet.

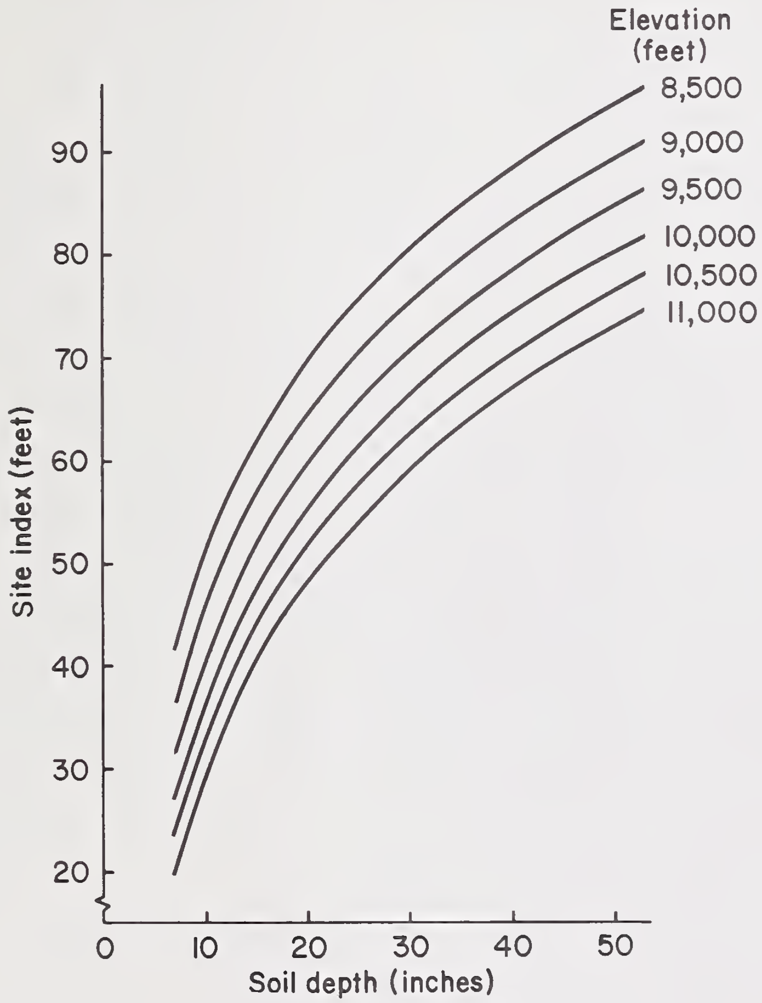

Figure 2.—Site index for Engelmann spruce on granitic soils in northern Colorado and southern Wyoming in relation to soil depth and elevation.

Discussion and Conclusions

Relative Importance of Factors

Soil depth to the top of the C horizon was the most important factor in determining site index in the study area. It accounted for 52 percent of the total variation in site index. This concurs with similar studies in the Rocky Mountains by Myers and Van Deusen (1960) who studied ponderosa pine (Pinus ponderosa Laws.), and Mogren and Dolph (1972) who studied lodgepole pine (Pinus contorta Dougl.).

As soil depth increased, the amount of water available to trees increased. The rate at which height growth increased with increasing soil depth was not constant, however. The rate of increase declined as soils became deeper, but did not reach the point where growth leveled off. The real value of soil depth as an indicator of site productivity lies in the fact that it is an integrator of those climatic factors that most affect height growth in trees: precipitation and temperature.

Elevation accounted for 13 percent of the total variation in site index. As elevation increases, height growth decreases because of lower temperatures and shorter growing seasons despite the increase in precipitation. However, stands of spruce with surprisingly good height growth were observed at 11,000 feet above sea level. The soils on these sites were very deep, and as a result height growth was good despite the short growing season at high elevations. If soil depth remained constant with increasing elevation, then height growth decreased along the environmental gradient because of a shorter growing season. But any change in soil depth was most important in affecting height growth, and offset any changes in temperature which occurred with elevational changes.

Sources of Unexplained Variation

All of the soils in the study area had developed largely from granitic rock, but the percentage of granite varied. Other parent materials found in the study area in combination with granite include slate, gneiss, schist, sandstone, dolomite, pumice, and conglomerate. Differences in soils throughout the study area, due to different combinations of parent materials, are thought to be the greatest single source of unexplained variation in site index.

The precipitation pattern was not uniform with respect to elevation throughout the study area. More precipitation fell west of the Continental Divide than east of it at the same elevation. Had the study area been located entirely east of the Continental Divide, some of the unexplained variation may have been eliminated.

A study of this type assumes that environmental factors are solely responsible for the different growth rates of trees. The inherited growth rates of individual Engelmann spruces may be different, however, and contribute to the unexplained variation.

Table 1.--Site index for Engelmann spruce on granitic soils in northern Colorado and southern Wyoming in relation to soil depth and elevation

Soil depth to C horizon (inches)	Elevation (thousands of feet)													
	8.6	8.8	9.0	9.2	9.4	9.6	9.8	10.0	10.2	10.4	10.6	10.8	11.0	11.2
7	40	38	36	34	32	30	29	27	26	24	23	21	20	18
9	47	45	43	41	39	37	36	34	32	31	29	28	27	25
11	53	50	48	46	45	43	41	39	38	36	35	33	32	31
13	57	55	53	51	49	47	46	44	42	41	39	38	37	35
15	61	59	57	55	53	51	49	48	46	45	43	42	40	39
17	64	62	60	58	56	55	53	51	50	48	47	45	44	42
19	67	65	63	61	59	58	56	54	53	51	50	48	47	46
21	70	68	66	64	62	60	59	57	55	54	52	51	50	48
23	73	70	68	66	65	63	61	59	58	56	55	53	52	51
25	75	73	71	69	67	65	63	62	60	59	57	56	54	53
27	77	75	73	71	69	67	65	64	62	61	59	58	56	55
29	79	77	75	73	71	69	67	66	64	63	61	60	58	57
31	81	78	76	74	73	71	69	67	66	64	63	61	60	59
33	82	80	78	76	74	73	71	69	68	66	65	63	62	60
35	84	82	80	78	76	74	72	71	69	68	66	65	63	62
37	85	83	81	79	77	76	74	72	71	69	68	66	65	64
39	87	85	83	81	79	77	75	74	72	71	69	68	66	65
41	88	86	84	82	80	78	77	75	73	72	70	69	68	66
43	90	87	85	83	81	80	78	76	75	73	72	70	69	68
45	91	89	87	85	83	81	79	78	76	74	73	72	70	69
47	92	90	88	86	84	82	80	79	77	76	74	73	71	70
49	93	91	89	87	85	83	82	80	78	77	75	74	73	71
51	94	92	90	88	86	84	83	81	79	78	76	75	74	72
53	95	93	91	89	87	85	84	82	80	79	77	76	75	73

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